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**Explosive Destruction System (EDS)
Main Trials
At DERA Porton Down, UK
Final Report**

DERA/CBD/CR000628

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**Explosive Destruction System (EDS) Main Trials At DERA Porton Down
Final Report**

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Abstract

This document describes the main trials of the Explosive Destruction System (EDS) for the Programme Manager for Non-Stockpile Chemical Materiel, US Army at Edgewood Chemical and Biological Centre, by the Defence Evaluation and Research Agency at Porton Down. The EDS is a system designed for the destruction of recovered chemical weapons by explosive opening and chemical neutralisation within a closed system.

This report describes technical progress during the period from 10 May 2000 to 7 July 2000, and includes toxic operations with nominally mustard (H) filled munitions. It also summarises the findings from the 1st, 2nd and 3rd interim reports and gives an analysis of these findings, together with those from the mustard munition campaign. This allows a set of conclusions on progress and results to be documented for the duration of the main trial, and gives suggestions for any future testing of the system before it enters operational use.

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1. Background

The Defence Evaluation and Research Agency (DERA) are currently undertaking a trials programme for the Programme Manager for Non-Stockpile Chemical Munitions (PM/NSCM), US Army, under contract with the European Research Office, US Army RD&SG. The Explosive Destruction System (EDS) is being tested against some of the recovered chemical warfare (CW) munitions stored at DERA Porton Down. A previous report, the 1st interim report, (DERA/CBD/PSP/Demil/407/00 dated 14 February 2000) detailed setup of the EDS at Porton Down; operator training; and preliminary trials without chemical agent. Another report, the 2nd /3rd interim report, (DERA/CBD/PSP/Demil/407/00 dated 31 May 2000) detailed the work carried out during DERA pre-trials with both bottled industrial phosgene (CG); toxic operations with nominally CG filled munitions and pre-trials with lab prepared and bottled mustard (H).

This document describes the work carried out during the phase of the trial dealing with toxic operations with nominally mustard filled munitions, and covers the period from 10 May 2000 to 7 July 2000. It also summarises the findings from the 1st, 2nd and 3rd interim reports and gives an analysis of these findings, together with those from the mustard munition campaign. This allows a set of conclusions on progress and results to be documented for the duration of the main trials and gives recommendations for any future testing on the system.

1.1 The Explosive Destruction System (EDS)

The EDS consists of a stainless steel pressure vessel approximately 10cm thick with an internal volume of around 200 litres, with a hinged door sealed with a metal-to-metal seal, rubber O-ring and Graylok clamp. The vessel is mounted on a trailer that provides working space, control panels, chemical supply tanks, pumps and other ancillary equipment.

The target munition, fill nominally identified with Portable Isotopic Neutron Spectroscopy (PINS) equipment and explosive configuration checked by X-ray, is mounted in a one-use disposable supporting frame (fragmentation suppression system, FSS) of approximately 1.5cm thick mild steel, with copper Charge, Linear, Cutting (CLC) mounted around the shell body. Two conical shaped charges are mounted on top of the support aligned with the munition's burster. The munition is opened by detonating the CLC and conical charges using high-voltage detonators supplied from a firing pack via four electrical feedthroughs in the door. The EDS vessel is rated for up to 454 grams (one pound) total of TNT equivalent explosive charge, which is sufficient to allow the explosive opening of munitions up to 4.5" calibre in shell configuration, or a Livens mortar.

Once the munition is opened, neutralising chemical appropriate to the nominal fill, is pumped from heated supply tanks on the EDS trailer into the vessel through high-pressure autoclave valves in the door. The vessel can also be heated if necessary, and is oscillated for the reaction time specified in the Standard Operating Procedures (SOPs) by a hydraulic ram mounted beneath the vessel. Samples are taken via sampling ports on the door manifold to confirm the munition's fill and that destruction of agent is complete. The vessel is then emptied to waste drums, and the liquid and solid waste move to a commercial hazardous waste handling facility. Any explosive or chemical agent residue remaining is treated according to local handling procedures.

1.2 The trials site

The EDS trailer and firing system are located in an enclosed metal-framed building on the Trials Range at DERA Porton Down. A small lean-to provides space for the monitoring equipment required (six Minicams and a GCMS). There is a limited amount of local mains power (240V 50Hz), and a 200kVA generator to supply the power for the EDS system at 208V 60Hz. Water is provided by bowser. Two canvas tents provide shelter for emergency decontamination stations, and there are three Portacabins to house the EDS control room and administrative personnel. The Porton Range has controlled access and trials activity is co-ordinated and controlled from a central Range Office with whom the EDS site is in communication by radio or mobile phone. In addition, there is a local communications setup with five portable radios worn by members of the trials team, with a speaker/microphone combination in the control cabin. CCTV coverage of the EDS trailer and the building is relayed from four cameras to TVs and video recorders also within the control cabin.

2. Work Completed in Period 10 May – 7 July 2000

2.1 Mustard Pre-Trials

As described in the 2nd/3rd interim report (DERA/CBD/PSP/Demil/407/00 dated 31 May 2000) a mustard pre-trial was carried out using two test-pieces consisting of lab-prepared mustard filled into emptied fire extinguishers. The second of these test pieces is described under ERO contract N68171-00-C-9021. The results from these test pieces confirmed that the system and procedures were in place to start on the destruction of mustard munitions.

2.2 Mustard munition campaign

With the system and procedures proved during the mustard pre-trials, the test moved onto the campaign with rounds nominally identified as containing mustard. PINS analysis had indicated a number of munitions that appeared to be most likely to contain mustard: these included a number of 4.2" mortars, 4.5" shells and 18 lb shells. Of these, four 4.2" mortars and four 4.5" shells were selected for the EDS trial. A decision was taken not to use the 18 lb shells at this stage as no liquid fill levels could be identified on the X-rays of these munitions. The PINS confidence level for these 18 lb shells was also lower than that for a number of the 4.2" and 4.5" munitions. In order to provide sufficient information for the EDS test campaign in the time available, it was decided to use those munitions that had a high PINS confidence, and whose X-rays showed clear evidence of a suitable level of liquid fill.

2.2.1 4.2" Mortar, PINS file 1061503, 10-12 May 2000

A 4.2" mortar, nominally assessed as containing mustard, was subject to the EDS SOPs using a Linear Shaped Charge (LSC) and conical charges to open the munition and 80 litres of monoethanolamine (MEA) as decontaminant. After fixing a switch on the fireset, firing operations proceeded as normal. After firing, minicam readings measuring vapour concentration of agent expressed as a Time Weighted Average (TWA) in mg m^{-3} indicated that the building was clear to enter and a zero reading on CAM was obtained after checking the vessel door. It was therefore deemed safe for personnel to re-enter the building. Attempts were made to collect liquid and vapour samples prior to addition of decontaminant. However, no liquid was present in the liquid sample bottle. Results from the analysis of the 2-hour decontaminated liquid sample indicated 10 ppm of mustard, the 3-hour sample contained 0.3 ppm and the 4-hour sample <0.1 ppm.

Relatively large quantities of Carbon Monoxide (CO) were generated in the vessel upon explosion, and, when venting and purging the vessel, this was released into the workplace through the charcoal filter assembly. This was monitored by FTIR, and once values reached a critical level (approximately 80 ppm as per UK regulations) all personnel were withdrawn from the building until such times as the CO concentration fell significantly below this level. Similar CO levels were observed during the phosgene munition campaign and throughout the mustard munition campaign.

The rinse was performed using a modified SOP on the instructions of the Test Director to route the rinse water through the drain valves. The operation then continued smoothly until the end of the procedure. The analysis of the vapour sample in the Tedlar bag indicated that it was safe to open the vessel door. Upon opening the vessel door, a small quantity of liquid was observed coming out of the vessel and the minicam reading above the vessel door showed 0.43 TWA. The door was monitored by UK CAM which indicated no mustard reading. The solid waste was removed from the vessel. This showed that the munition had been breached by the linear charge and there was evidence that both conicals had fired. A deposit of putty-like material was noticed near the lip of the door. When this deposit was disturbed to take solid samples a reading of 3 bars on UK CAM occurred. The minicam above the vessel door showed 0.72 TWA. UK CAM continued to show between 2 and 3 bars and the crew removed the door seal in order to take more solid samples. A small quantity of sludge in the catch tray under the vessel gave a 2 bar reading on UK CAM. A reading of 1.6 TWA was obtained from the minicam over the vessel door.

During the decontamination of the vessel interior it was discovered that some material had escaped treatment. The deposited material was described as a "varnish" – a crust trapping active mustard which, when scraped, gave enough mustard to be detected. This material was confirmed as mustard in subsequent laboratory analysis. This varnish covered the entire door, door protector plate and the entire vessel interior. It was noted that the back of the vessel had heavy deposits which gave a 3 bar reading on UK CAM. A decontaminant solution was sprayed onto all vessel surfaces, including the door and door protector plate. The black deposits were then removed by scrubbing (task required 5 applications of decontaminant solutions and 5 scrubbing sessions). Minicam readings above the vessel door varied between 1.06 and 2.09 TWA. It was observed that the decontaminant solution of 2 parts alcohol/2 parts 20% caustic/1 part chlorine bleach worked well when cleaning the vessel.

2.2.2 4.2" Mortar, PINS file 1061603, 15-18 May 2000

A 4.2" mortar, nominally assessed as containing mustard, was treated in the EDS in a similar manner to 2.2.1. Firing operations proceeded as normal after a short delay (to untangle the firing cord). Minicam readings indicated that the building was clear to enter and a zero reading on CAM was obtained after checking the exterior of the vessel door. After firing, attempts were made to collect liquid and vapour samples. However, no liquid was present in the liquid sample bottle. A dichlormethane rinse of the liquid sample bottle showed the presence of chlorobenzene. This material is used in the manufacture of mustard and is an indicator that the munition may have had a mustard fill.

It was also noted that when the vessel was stopped in the nose up position for DAAMS tube replacement the thermocouple was not in contact with the liquid and was reading from the air. The MEA solution was, however, touching the heaters and may be hotter than the air reading. Because the flash point of MEA is close to 75°C it was decided to turn off the vessel heaters. It was agreed that this would be incorporated into SOPs in the future. Results from the analysis of the 2-hour liquid sample indicated 1 ppm of mustard.

During the initial rinses the operators reported that the noise of the pump changed and that the pump itself was shaking heavily. The rate of flow of the rinse solutions into the vessel was also observed to be slower than normal. Due to problems with the supply pump the second rinse was not carried out. The analysis of the vapour sample in the Tedlar bag indicated that it was safe to open the vessel door. Upon opening the vessel door a small quantity of liquid was observed coming out of

the vessel and the minicam reading above the vessel door was 0.28 TWA. The door was monitored by UK CAM which gave no reading. The solid waste was removed from the vessel. The munition had obviously been breached by the linear charge and there was evidence that both conicals had fired. The deposit on the vessel consisted of soot and tar with no evidence of the "varnish" type deposit discovered in munition 1061503. The minicam above the vessel door showed 0.28 TWA rising to 3.34 TWA. UK CAM showed 3 bars when debris was scraped from the bottom of the vessel. A deposit was found which had the appearance and texture of black chewing gum.

During decontamination it was again noted that black sooty material was present and that it "looked as if there had been a fire in the vessel". The vessel deposits were reported as being of a different nature than during the previous munition run. This made the vessel easier to clean as the sooty deposits were easier to remove than the tarry deposits. Decontamination of the vessel proceeded according to SOPs until the line bulged while the team were emptying the metal drip tray into drum 3 using the peristaltic pump. The team replaced the line and continued. Again, the line bulged and was changed a further two times. The team then proceeded to look for blockages in the pump line and removed the fitting connected to drum 3. The line pressurised and split, showering one of the team members with decontaminant solution from the drip tray. The operator was quickly taken to the undressing station where contaminated clothing was removed and the operator was sent for a shower and medical assessment. A subsequent analysis of the decontaminant solution indicated that no agent was present in the sample and therefore the operator was not exposed to mustard. Vessel cleaning operations proceeded according to plan after this incident. An analysis of this incident showed that these blockages occurred when cloth fragments penetrated filters and blocked the open system. The risk assessment associated with this activity was amended in order to minimise the risk of such a situation occurring again.

At this stage a two week break was scheduled to allow trial participants to attend the CWD2000 conference in the Hague, where the US Test Director was giving a presentation on the EDS. The second week of down time gave the opportunity to carry out maintenance procedures.

2.2.3 4.2" Mortar, PINS file 1061602, 5-9 June 2000

A 4.2" mortar, nominally assessed as containing mustard, was treated in the EDS in a similar manner to 2.2.1 and 2.2.2. Firing operations proceeded as normal. Minicam readings indicated that the building was clear to enter and a zero reading on CAM was obtained after checking the vessel door. Liquid and vapour sampling was undertaken, however, no liquid was present in the liquid sample bottle. A dichlormethane rinse of the liquid sample bottle showed the presence of chlorobenzene. Results from the analysis of the 2-hour liquid sample indicated 2.9 ppm of mustard; the 3-hour sample was analysed as 2.4 ppm and the 4-hour sample as 0.72 ppm.

After the hot water rinse a vapour sample was taken in a Tedlar bag. This was then absorbed onto a DAAMS tube and the DAAMS tube was placed on a "dynatherm" to desorb. The monitoring personnel asked for permission to clear the monitoring room as they had smelled an odour that was recognised as a mustard breakdown product. The analysis of this tube showed greater than 7500 nanogrammes of mustard. The Tedlar bag sample after the helium purge still showed 792 nanogrammes of mustard and a decision was made to do another helium purge. A subsequent Tedlar bag sample showed 808.3 nanogrammes of mustard. It was apparent from these results that an unknown, but significant, amount of mustard had not been destroyed and remained in the vessel.

Due to the high levels of mustard shown by the analysis of the Tedlar bags a decision was taken not to open the door of the vessel that day.

The following day another helium purge was carried out followed by a Tedlar bag sample. This time the sample showed 1415 nanogrammes of mustard. A decision was made to rinse the vessel for 2 hours with water at 100°C in an attempt to lower the mustard level and the vessel was left to cool overnight. After another helium purge a Tedlar bag sample was taken which showed that no mustard was present. After opening the door the minicam reading above the vessel door was 0.03 TWA. The solid waste was removed from the vessel. This showed that the munition had been breached by the linear charge and there was evidence that both conicals had fired. The appearance of the vessel was similar to that of munition 1061603 with sooty deposits. The minicam above the vessel door showed 0.01 TWA with a maximum of 0.08 TWA during the removal of the solid waste.

The team reported that the interior of the vessel was much cleaner than the previous munition and was therefore much easier to clean. The rinsate sample showed the presence of mustard breakdown products and it was concluded that the 2 hour treatment with water at 100°C was highly effective at destroying residual and polymerised mustard, and should be incorporated into the EDS SOPs for mustard munitions.

2.2.4 4.2" Mortar, PINS file 1061505, 13-15 June 2000

A 4.2" mortar, nominally assessed as containing mustard, was treated in the EDS in a similar manner as documented above. Firing operations proceeded as normal. Minicam readings indicated that the building was clear to enter and a zero reading on CAM was obtained after checking the vessel door. After firing, an attempt was made to collect a liquid sample. However, no liquid was present in the liquid sample bottle. A dichlormethane rinse of the liquid sample bottle showed the presence of chlorobenzene. Results from the analysis of the 2-hour liquid sample indicated 1.4 ppm of mustard; the 3-hour sample was analysed as 1.2 ppm and the 4-hour sample as 0.4 ppm.

A hot water rinse and a helium purge were carried out. Analysis of a Tedlar bag sample showed 2222.26 nanogrammes of mustard. The vessel was then treated for 2 hours with water at 100°C and left to cool overnight. After a water rinse and a helium purge a Tedlar bag sample was taken which showed that no mustard was present. These results fully justified incorporating the hot water treatment into the EDS SOPs for mustard munitions. After opening the door the minicam reading above the vessel door was 0.06 TWA. The solid waste was removed from the vessel. This showed that the munition had been breached by the linear charge and there was evidence that both conicals had fired. Again, the vessel interior was relatively clean.

2.2.5 4.5" Shell, PINS file 1040806, 19-21 June 2000

A 4.5" shell, nominally assessed as containing mustard, was treated in the EDS in a similar manner to the mustard-filled 4.2" mortars. Before the munition arrived on site it was observed that the heater on tank 3, containing monoethanolamine, was not operable. Maintenance crew personnel went in to diagnose the problem and discovered that electrical fuses had blown. Operations commenced after an approximate delay of 90 minutes once the fuses were replaced. Firing operations then proceeded as normal. Minicam readings indicated that the building was clear to enter and a zero reading on CAM was obtained after checking the vessel door. After firing an

attempt was made to collect a liquid sample. However, no liquid was present in the liquid sample bottle. A dichloromethane rinse of the liquid sample bottle showed no chlorobenzene. Results from the analysis of the 2-hour liquid sample indicated 0.5 ppm of mustard; the 3-hour sample was analysed as <0.2 ppm and the 4-hour sample as <0.2 ppm.

A hot water rinse was carried out and the vessel was then treated for 2 hours with water at 100°C and left to cool overnight. After an ambient water rinse and a helium purge, a Tedlar bag sample was taken which showed that no mustard was present. After opening the door the minicam reading above the vessel door was 0.00 TWA. The solid waste was removed from the vessel. This showed that the munition had been breached by the linear charge and there was evidence that both conicals had fired. Again, the vessel interior was relatively clean.

2.2.6 4.5" Shell, PINS file 1040708, 22 June 2000

A 4.5" shell, nominally assessed as containing mustard, was placed in the EDS in a similar manner to the 4.5" shell PINS 1040806. During the closing and sealing of the vessel door after the munition had been loaded a large quantity (approximately ½ pint) of hydraulic fluid was observed to be leaking from the vessel. This was caused by the failure of a hydraulic seal. Operations were terminated and the munition was removed from the EDS. A maintenance crew overhauled all hydraulic nuts on the EDS.

2.2.7 4.5" Shell, PINS file 1040708, 26-28 June 2000

A 4.5" shell, nominally assessed as containing mustard, was treated in the EDS in a similar manner to the munitions above. Firing operations proceeded as normal. Minicam readings indicated that the building was clear to enter and a zero reading on CAM was obtained after checking the vessel door. Again, an attempt was made to collect a liquid sample. However, no liquid was present in the liquid sample bottle. A dichloromethane rinse of the liquid sample bottle showed the presence of chlorobenzene. Results from the analysis of the 2-hour liquid sample indicated < 0.2 ppm of mustard (although a very small mustard peak was present to confirm that the munition actually did contain mustard), the 3-hour sample was analysed as <0.2 ppm and the 4-hour sample as <0.2 ppm.

A hot water rinse was carried out. After completing the drain the operator attempted to bring the vessel to slightly above horizontal. The home button was pressed to verify that the vessel was all the way home. When the oscillation start button was pressed the usual sound was heard but the panel cut out. The vessel remained in the nose down position. The trip switches were checked and it was confirmed that they were still switched on. Fault diagnosis commenced but it was not obvious where the specific fuse was located in the unit. Eventually the fuse panel was located in the fuse unit and, on replacement of a fuse, oscillations re-commenced. During addition of the water for the water treatment the pump ceased to operate. However, as over 60 l had been added the decision was taken to proceed with this amount (instead of the full 80 l). The vessel was then treated for 2 hours with water at 100°C and left to cool overnight. A new pump was procured for the next days operations.

After an ambient water rinse and a helium purge a Tedlar bag sample was taken which showed that no mustard was present. After opening the door the minicam reading above the vessel door was 0.00 TWA. The solid waste was removed from the vessel. This showed that the munition had been

breached by the linear charge and appeared to be in multiple pieces and there was evidence that the conicals had fired. Again, the vessel interior was relatively clean.

2.2.8 4.5" Shell, PINS file 1040807, 29 June – 3 July 2000

A 4.5" shell, nominally assessed as containing mustard, was treated in the EDS in a similar manner to those above. Firing operations proceeded as normal. Minicam readings indicated that the building was clear to enter and a zero reading on CAM was obtained after checking the vessel door. After firing an attempt was made to obtain a liquid sample. However, no liquid was present in the liquid sample bottle. Results from the analysis of the 2-hour liquid sample indicated 0.8 ppm of mustard; the 3-hour sample was analysed as 0.4 ppm and the 4-hour sample as <0.2ppm.

A hot water rinse was carried out and the vessel was then treated for 2 hours with water at 100°C and left to cool overnight.

After an ambient water rinse and a helium purge a Tedlar bag sample was taken. This was analysed by minicams at 0.27 TWA. This result was such that it was safe to open the vessel door. After opening the door the minicam reading above the vessel door was 0.23 TWA. The solid waste was removed from the vessel. This showed that the munition had been breached by the linear charge and appeared to be in multiple pieces and there was evidence that conicals had fired. Detonation of this munition appeared to be more powerful than PINS 1040708. Again, the vessel interior was relatively clean.

2.2.9 4.5" Shell, PINS file 1040804, 4 - 6 July 2000

A 4.5" shell, nominally assessed as containing mustard, was treated in the EDS in a similar manner to those above. Firing operations proceeded as normal. Minicam readings indicated that the building was clear to enter and a zero reading on CAM was obtained after checking the vessel door. A liquid sample only was collected, however, no liquid was present in the liquid sample bottle. Results from the analysis of the 2-hour liquid sample indicated 0.8 ppm of mustard; the 3-hour sample was analysed as <0.2 ppm and the 4-hour sample as <0.2 ppm.

A hot water rinse was carried out and the vessel was then treated for 2 hours with water at 100°C and left to cool overnight.

After an ambient water rinse and a helium purge a Tedlar bag sample was taken. This was analysed by minicams at 0.00 TWA and it was declared safe to open the vessel door. After opening the door the minicam reading above the vessel door was 0.00 TWA. The solid waste was removed from the vessel. This showed that the munition had been breached by the linear charge and there was evidence that conicals had fired. Again, the vessel interior was relatively clean.

3. Summary of the Main EDS Test Programme

3.1 Pre-trial Activity

The series of planning meetings held at Porton Down in early 1999, and visits by personnel to observe the EDS in operation in the US, allowed a suitable trials site to be chosen and equipped at DERA Porton Down.

DERA staff carried out PINS analysis of candidate munitions. 140 munitions were studied with PINS and 39 were selected as likely mustard or phosgene filled. For the selected munitions X-rays were collated, reviewed and in some cases reacquired. DERA carried out preliminary laboratory work throughout Jun-Sep 99 to develop analytical methods where necessary and to ensure that staff were trained and competent in the US supplied procedures.

The UK NBC protective clothing was tested against the various chemicals used as neutralising solutions for the EDS trials, namely monoethanolamine and sodium hydroxide.

3.2 Transport of EDS Trailer and Explosives

The EDS trailer and explosives arrived by air and although the trailer suffered minor damage it arrived in an operable condition. It was installed at the test site on 9 October 1999.

3.3 Trial Setup, Training and Readiness Review

US personnel began arriving at DERA Porton Down from 12 October 1999 and worked in conjunction with UK personnel to set up the ancillary equipment and connecting infrastructure. Planned upgrades to the manifold and hydraulic system were carried out and the sampling, monitoring and data collection equipment was installed.

Sandia National Laboratory personnel ran a training course in parallel with the equipment setup. The training included a number of simulated operations with dummy munitions and neutralising chemicals, but without explosives. The US explosives were tested on UK empty munition cases. This led to a redesign of the FSS and conversion of a number of the FSS to accommodate UK 4.2" mortars.

The training and setup phase culminated in a Test Readiness Review (TRR) in the period 1-5 November 1999 carried out by personnel from PMCD (Safety), PMCD(Safety and Industrial Hygiene), ECBC Safety Office and PMNSCM. All findings from the review were resolved and the TRR chairman concluded: "Throughout the conduct of the test readiness review it was evident that the EDS operations team had a thorough understanding of the operations and procedures. They demonstrated superior proficiency in performing tasks in all levels of personal protective equipment".

3.4 Pre-trial Explosive Operations

With the successful conclusion of the TRR, the EDS team moved into final pre-trial simulations, using explosives but no agent from 8-19 November. This included testing the system with munitions that had been sealed with plaster of Paris and double bagged munitions.

In general, these trials were successful although during the Livens mortar trial on 18 November a certain degree of damage to the EDS vessel occurred. This damage, although relatively serious, was not considered to be detrimental to its performance against the obligated 1 pound (454g)-TNT equivalent specified in the SOPs.

3.5 Phosgene Pre-trials

In early December 1999 a 6 kg net cylinder of industrial phosgene was processed in the EDS by using an explosive charge to expose the agent to a decontaminant (sodium hydroxide) according to the EDS SOPs. During the drawing of the neat liquid sample it was noted that there was a small leak from the liquid sample port and the liquid sample bottle itself. The neat phosgene appeared to have attacked the sealing material (ethylene-propylene dimonomer, EPDM). Another problem encountered was that the hydraulic oscillation system was unable to lift the full weight of the vessel, target, fill, decontaminant and frag suppression system.

At this stage, it was decided to halt the test for the Christmas break and to effect the required modifications to the system. A lengthy period of redesign and part manufacture followed with the US team returning to DERA Porton Down in late February to carry out the modifications. This period and the subsequent pre-trials will be described in the report under ERO contract number N68171-00-C-9021.

3.6 Phosgene Munition Campaign

This campaign started with the destruction of two 4" Stokes mortar rounds, nominally assessed as containing phosgene. These were treated in the EDS according to SOPS for phosgene munitions. On both occasions, a small amount of phosgene was detected above the vessel door when it was opened.

A 4" Stokes mortar, nominally assessed as containing phosgene with tin, was then attempted. This time a helium flush was planned to alleviate the problem of detecting phosgene above the vessel door. On detonation, the pressure and temperature in the vessel were significantly higher than with just phosgene (104 Psia and 40 degrees Celsius compared to approximately 50 psia and 19 degrees Celsius). During the helium purge a large quantity of orange-yellow smoke was seen penetrating the charcoal filter on the waste barrel and the building had to be evacuated. However, as no phosgene was detected on the minicams, the helium purge was deemed to be a success and was written into the SOPs.

As a result of the "unusual" behaviour of temperature and pressure, as well as the smoke, it was decided to proceed with further munitions whose PINS spectra were similar to this munition before attempting the Livens, with its much greater agent fill.

Another three 4" Stokes mortars, nominally assessed as containing phosgene with tin were destroyed. Changes were made to the SOPs to try to eliminate, or at least reduce, the orange-yellow smoke, which were only partially successful. An attempt to trap the smoke and subsequently analyse it proved inconclusive. All these munitions showed an elevated temperature and pressure reading compared with the phosgene only filled munition.

It was the concern over the temperature and pressure spike on detonation that led to the decision not to detonate the phosgene Livens. At this point, the phosgene munition campaign was concluded.

3.7 Mustard Pre-trials

After general maintenance a 1.8 kg net cylinder of lab-prepared mustard was processed in the EDS. Analysis of the liquid samples at 2, 3 and 4 hours gave mustard levels of 400 ppm, 10 ppm and less than 0.1 ppm respectively giving an indication that the majority of the mustard had been destroyed. However, upon opening the door it was apparent that either some residues remained, in the vapour phase or off gassing from residue in the door fixtures as the UK CAM showed 5 bars (i.e. battlefield significant levels). Minicam readings recorded 29 TWA. After a helium flush it became apparent that the liquid sample and drain lines were contaminated (readings of up to 75 TWA were recorded from minicams sampling the drain line).

In order to prevent this changes to the SOPs were suggested which included a helium purge and more thorough rinsing of the sample and drain lines. A further test was scheduled to confirm the effectiveness of these SOPs and this is described under the report for ERO contract N68171-00-C-9021.

3.8 Mustard Munition Campaign

This campaign is described in detail in section 2 of this report and the main points are summarised briefly below.

Four 4.2" mortars and four 4.5" shells were selected for the mustard munition campaign. During the first of the mustard-filled 4.2" mortars the operation proceeded smoothly and the analysis of the Tedlar bag sample, taken from the EDS after the neutralisation and rinsing stages were complete, indicated that it was safe to open the vessel door. Once the door was open both Minicam and UK CAM readings indicated <0.5 TWA and no bars, respectively. The munitions fragments and FSS were removed and a deposit of putty-like material was discovered near the door which, when disturbed, gave a reading of 3 bars on UK CAM. Closer examination of the vessel revealed similar deposits over the interior of the vessel which were crusts trapping active mustard. Decontamination of these deposits and cleaning the vessel required many applications of decontaminant solution and several scrubbing sessions. Similar deposits were found during the destruction of a second Stokes mortar.

Although the presence of these deposits was undesirable in so far as they added to the time and effort required to decontaminate and clean the vessel afterwards, they did give relatively low TWA values for mustard throughout. The destruction of the munitions was therefore considered a success. However, during the destruction of a third Stokes mortar the Tedlar bag analysis showed high levels of mustard were present in the vessel after decontamination, possibly due to significant amounts of polymerised material. This led to the introduction of a 2 hour treatment with boiling

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water in order to lower the level of mustard in the vessel. The success of this treatment led to it being incorporated into the SOPs for mustard munitions.

The remaining 4.2" mortar and subsequent destruction of four 4.5" shells gave very low readings and in spite of few hardware and electrical problems, were deemed successful. These problems, although annoying, gave the EDS team an opportunity to carry out fault finding procedures and to find solutions to practical hardware problems as they arose. All of which has contributed to the store of knowledge for when this system enters operational use in the US early next year.

The EDS test manager used these last munitions tests as an opportunity to vary certain of the test parameters and procedures in an attempt to streamline the destruction process and obtain consecutively good results. Unfortunately, the time left available until the conclusion of the main trials programme was insufficient to obtain all the data required for complete confidence in the destruction of mustard filled munitions.

An additional period of work to carry out the destruction of a further 8-10 munitions will be required. This will include the destruction of munitions which have been treated with Plaster of Paris and/or those that are contained within polythene bags. This will be the subject of a new research proposal.

4. Conclusions

The EDS trial has demonstrated the system's ability to be transported, set up, commissioned, handed over to trained operators and operated against explosively configured chemical filled munitions.

The EDS system and operators have passed the first Test Readiness Review to be performed on the equipment.

Interfaces between the US and UK teams on-site, as well as with the UK support personnel in range control and analytical laboratories, have been well practised and have worked smoothly throughout the main trial.

Although successful at containment and decontamination and destruction of chemical agent, the EDS as originally configured proved unable to meet the chemical challenge of taking neat agent samples as noted during the phosgene munition campaign. Three months of development work has led to a system that is robust against this challenge.

Relatively large quantities of CO were generated in the vessel upon detonation, and when venting and purging the vessel this was released into the workplace through the charcoal filter assembly. This was monitored by FTIR, and once this reached a critical level (approximately 80 ppm as per UK regulations) all personnel were withdrawn from the building until such times as the CO concentration fell significantly below this level. These CO levels were observed during the phosgene and mustard munition campaigns.

The EDS has successfully destroyed six legacy phosgene-containing munitions with no significant release of agent. Changes to SOPs have led to the final four phosgene munitions being destroyed with no measurable release of agent at all.

The mustard pre-trials indicated that changes to the SOPs were required to ensure that residual mustard was cleared from the vessel attachments. These were amended to incorporate a helium purge before opening the vessel door and more thorough rinsing of the sample and drain lines.

After the first two 4.2" mortars in the mustard munition campaign, it became evident that deposits of crusty material trapping active mustard were still present in the EDS vessel at the end of the procedure. This led to the introduction of the 2 hour boiling water treatment that successfully removed these deposits and left the vessel much easier to decontaminate and clean.

During the destruction of the final munitions in the mustard campaign, the EDS test director reached the stage where he could vary certain of the test parameters and procedures. This was done in an attempt to streamline the destruction process and obtain consecutively good results that are required to refine the SOPs. Unfortunately, the time left available until the conclusion of the main trials programme was insufficient to obtain all the data required for complete confidence in the destruction of mustard filled munitions. A further period of work from Sep – Dec 2000 will be required.

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It soon became obvious during the trial that the original proposal involving the destruction of sixty munitions was grossly optimistic. The description of each munition clearly indicates that to destroy the contents with a minimal release to the atmosphere is a time-consuming process of at least 2-3 days per munition. This is particularly relevant in respect of mustard munitions containing an amount of polymerised mustard. The original costings were based on the assumption of a trial period of 12 working weeks in addition to installation, commissioning and break up work. The EDS has been in residence at DERA Porton Down since 19th of October 1999, and was operational for explosive pre-trials at the end of November 1999. The period April - May 2000 is covered by an additional ERO contract covering modification work and the testing of the modified system on CG and mustard filled test pieces (1 of each). However, in the 18 weeks of operations covered by the main trial the EDS has accomplished the following:

Operation	Number of munitions	Type of munitions
Pre-trial explosive tests	3	18 lb shell, 4.2" mortar, Livens
Phosgene Pre-trials	1	Test piece
Phosgene munitions	6	4" Stokes mortars
Mustard pre-trials	1	Test piece
Mustard munitions	8	4.2" mortar, 4.5" shell

(2 other test pieces are discussed during the report on the testing of the modified system under ERO contract N68171-00-C-9021).

In almost every case, each munition and test piece has presented unique circumstances that have required the test and evaluation staff to modify and revise the existing EDS SOPs to respond to that particular situation. In certain instances, new procedures in addition to the existing SOPs have had to be developed to deal with problems such as the mustard deposits on the vessel interior. This has also led to very long working days that increased the manpower required per munition. Numerous hardware problems have been documented (32 observation reports have been produced over the trial period). Each of these has required the test and evaluation staff to solve the problem, usually in a limited time frame. As each hurdle has been overcome, the operating staff have gained confidence that they are capable of solving a range of electrical and mechanical failures and these solutions have been documented for future reference.

In conclusion, the test and evaluation of the EDS system at Porton Down has been a success. Confidence in the operational use of the system has been gained, and the system has successfully destroyed a number of phosgene and mustard munitions with minimal or no releases to the atmosphere. A further short test period is required to finish gathering data that will allow refinement of the SOPs for mustard munitions. It may also be necessary to destroy a phosgene/tin Livens if it is possible to overcome the problem of the orange-yellow gas production. This will ensure that when the system returns to the US it will be fully operational against both phosgene and mustard munitions, including those that have been treated with Plaster of Paris and/or those that are contained within polythene bags.

5. Recommendations for Future Testing and Evaluation of the EDS System

In order to gather sufficient data to allow full confidence in the ability of the system to deal with a range of munitions and munition fills, there is a requirement for a further 8-10 munitions to be destroyed. The system should also be tested against munitions that have been treated with Plaster of Paris and/or those that are contained within polythene bags. The majority of these will be mustard munitions, although there is a possibility that a phosgene/tin Livens may be a candidate munition if the problem of the orange-yellow smoke production can be overcome. There is also the problem of a potential large pressure and temperature rise of unknown magnitude due to the larger quantity of agent contained in the Livens projectile. Extreme care will need to be exercised if this option is taken and it is suggested that this should be the final test in this current test and evaluation phase.

An additional period of testing will allow the test and evaluation staff to streamline the destruction process and obtain the results which are required to further refine the SOPs. After this further period of testing full confidence in the system should be realised. There will then be minimal delay until the system becomes fully operational upon its return to the US.

6. Annex A Financial Information

The tables below give an indication of the financial breakdown and approximate spend for each of the 1st, 2nd, 3rd and final reporting periods for the main EDS trial. All figures are exclusive of VAT, and are given in US dollars.

Table 1. 1st Interim Report – covering period up to 30 November 1999.

	Manpower	Facilities	Materials	Transport	Total
PINS	17,015	0	0	0	17,015
Meetings, visits, Management	23,855	0	0	1,120	24,975
Analytical development	18,980	0	0	0	18,980
Site Setup	5,880	1,200	870	0	7,950
Range Support	2,450	53,335	0	0	55,785
Pre-trials	36,215	2,730	15,685	70,365	124,995
<i>Total</i>	104,395	57,265	16,555	71,485	249,700

Table 1; Approximate financial breakdown for period up to 30 November 1999.

Table 2. 2nd and 3rd Interim Reports – covering period 1 December 1999 – 2 May 2000,

	Manpower	Facilities	Materials	Transport	Total
Pre-trials with phosgene	20,519	9,810	6,724	0	37,053
Phosgene munition campaign	260,905	70,992	31,053	0	362,950
Pre-trials with mustard	25,966	9,810	8,212	0	43,988
Incineration of waste	0	10,271	750	300	11,321
Analytical Support	37,252	6,836	0	0	44,088
<i>Total</i>	344,642	107,719	46,739	300	499,400

Table 2; Approximate financial breakdown for period 1 December 1999 – 2 May 2000

Table 3. Final Report – covering period 3 May – 7 July 2000 (with the exception of the period covered by the additional contract)

	Manpower	Facilities	Materials	Transport	Total
Mustard munition campaign	107,173	29,115	15,082	0	151,370
Incineration of waste	0	12,680	750	300	13,730
Analytical Support	14,600	0	0	0	14,600
Return of EDS	-	-	-	70,000*	70,000
<i>Total</i>	171,773	41,795	35,832	300	249,700

Table 3; Approximate financial breakdown for period 3 May – 7 July 2000

* This sum has been retained to pay for the return of the EDS after completion of the additional contracts

These figures make up the total value of the contract, \$998.800.

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